Analyzing Ventilation Effects of Different Apartment Styles by CFD

Xiaodong Li
Associate Professor
School of Municipal & Environmental Engineering, Harbin Institute of Technology,
Harbin, Heilongjiang, China
Email: lxd8802@163.com

Lina Wang
Shenzhen AdvArc Building Energy CO., LTD
Shenzhen, 518001
Email:wanglinahit@yahoo.com.cn

Zhixing Ye
Shenzhen AdvArc Building Energy CO., LTD
Shenzhen, 518001
Email:advarc@advarc.com

Abstract: With more attention being paid to residential apartments, designers have begun to focus their efforts on how to make a design that is not only functional but also practical. This paper gives a summary of a detailed Computational Fluid Dynamics (CFD) study of flows in different apartments in Guangzhou City. The outdoor temperature is 27 and outdoor wind velocity is 1.8m/s, which comes from a southeast direction. Although all the apartments have the same inner layouts, results show apartments located in different directions have distinct ventilation environments. By compare the velocity fields of each apartment in four directions, results show that the apartment in the east has favorable ventilation effects. There are some disadvantages of other apartments. Also, simulation results give designers some advice for designing the layouts. Furthermore the paper provides information to consumers when they choose apartments.

Key words: Apartment, ventilation effect, design style, CFD

1. INTRODUCTION

House is an important place in people's daily life. It not only provides people a comfortable environment place, but also offers people a private space. In China, apartment is still the main choice for most people because large number of people and limited area. Recently, there is a great boom for residential construction with the developing of living standard. Residential apartment has become a new consumption hot spot. But when people choose apartments for themselves, they only focus their attention to the size and surroundings. Actually not only the size and surroundings of the apartment are should be considered, but also the apartment type design is a necessary factor. A favorable type can provide a comfortable indoor environment and save energy, because good natural ventilation decreases the time use air-conditioning.

In an idea house type, each part has its independent character at the same time every part unites together with a steady relation. All of them have reasonable distribution to create a best indoor environment. So house type should be based on the idea that people must be put on the first place. Designers should consider human's physical and psychological requirements adequately. The basic physical requirements of house include size, sunlight, ventilation, temperature. And the psychological requirements include safety degree, privacy degree, domain sense, and familiarity sense. This paper will analyze the ventilation index for different house types in different direction. Ventilation can remove indoor pollutants effectively. Also it creates an easeful residential environment and has important effects on people's feeling.

Based on CFD simulation approach which considers the relation between house and atmospheric boundary, and the connection between outdoor ventilation and indoor environment, the aim of present paper is determine the ventilation effects of different house type to help people when they choose apartments for themselves and help designers to make best designs not only comfortable but also save

energy.

2. CFD METHOD

2.1 Geometry of Model

A new apartment building located in Guangzhou City is chosen as the model of this case. The building has four apartment types which are designed with same inner structures but located in different directions. It is shown as Fig.1. Four apartments are connected together by a hollow part which has no effect on the ventilation. The detailed inner information of the apartment (East one) is shown in Fig.2. There are living room, dining room, three bedrooms, kitchen, workroom, toilet, bathroom, and three balconies in one apartment. Dimension of the apartment is 14×10×3m. The balconies are all in the open air. Because the objective of this paper is simulating ventilation conditions of the apartment, windows and indoor doors are supposed to be open, which are shown in Fig.3. The grey parts represent open windows and open doors, which are considered as the tunnels of wind. In this simulation, the apartments are occupied by nothing in this paper and there is no heat source. Ventilation effect is the only aim of this paper.

Fig.1 Plane layout of building

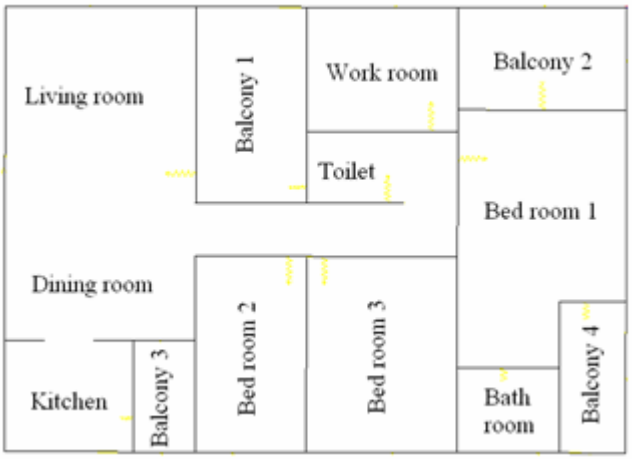

Fig.2 Function of each room

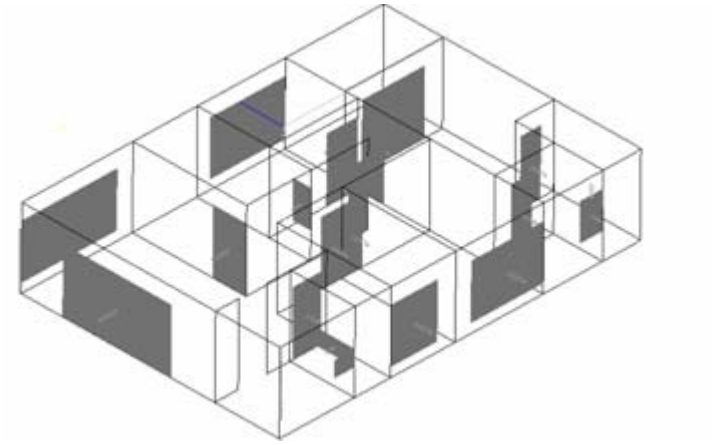

Fig.3 Detail information about doors and windows

2.2 Grid Generation

The correctness and accuracy of simulation results depend highly on grid quality. Unstructured grids method is usually used in the situation with complicated geometries. The layout of apartment model is simple and there are no obstacles and people in the simulation process, so structure grids method is chosen to discretize the space. Furthermore, structured grids have higher quality than unstructured grids. To establish grid independent solutions two grids were evaluated. The first kind of grid has 16373 number nodes resulting in a volume of grid 14417 hexagonal cells. In order to get accurate results, on the base of the coarse grids, the second kind of grid is made up of total 89706 number nodes including x, y, z edges, which result in 83847 hexagonal cells. The later one is finer than the former one.

2.3 Turbulence Model

Currently the most widely used turbulence

model in the industry is the standard k– model of Lauder and Spalding (Launder & Spalding, 1974), since it has been validated in a variety of turbulent flows and it is relatively economical in computation. The k– model provides two transport equations of the turbulent kinetic energy (k) and its dissipation rate ( ) respectively to model the velocity and length scales of turbulent flows. The standard k– model assuming isotropic turbulence was adopted to describe turbulent transport. This choice is a good compromise for a realistic description of turbulence and computational efficiency (Jones & Whittle, 1992). Above all standard k– model is applied in this simulation.

2.4 Boundary Conditions

Outdoor temperature is 27 . Wind comes from south east direction and its velocity is 1.8m/s. In this simulation, the wind velocity is not directly added on the windows and doors. Actually a real atmospheric boundary is set up to simulate the real conditions, which is more close to the outdoor environment. The boundary layer thickness is 270m. The initial wind values are set on the atmospheric boundary. Because its direction is south east, the south plane and the east plane are considered atmospheric boundary, from where the wind comes. While the north and the west plane are designed two planes from which the wind ejects. Walls, ceiling and floor are adiabatic in this simulation. There are no other buildings around the apartments.

3. RESULTS AND DISCUSSIONS

3.1 Flow Patterns

The flow pattern is one of the necessary concerns during preliminary design period or when people choosing the favorable apartment style since an outline of the indoor wind microenvironment can be obtained simply by observing the flow behaviors. Attentions are usually paid to strong vortices and ventilation effect because those phenomena may cause discomfort to people and cannot blow away pollutants. In addition, perfect apartment structure utilizes natural ventilation effectively during some periods in a year which make energy saving.

Apartments with same inner structures maybe own different ventilation effects. This is attributed to different directions. So the velocity fields of 4 cases are shown in Fig.4, Fig.5, Fig.6, and Fig.7. All the velocity fields are across the plane y=1.5m. By these comparisons, the ventilation flows in the whole apartment are shown clearly.

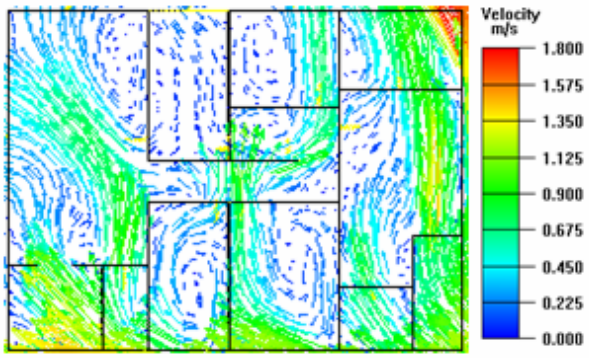

Fig.4 Velocity field across Y=1.5m in the east apartment

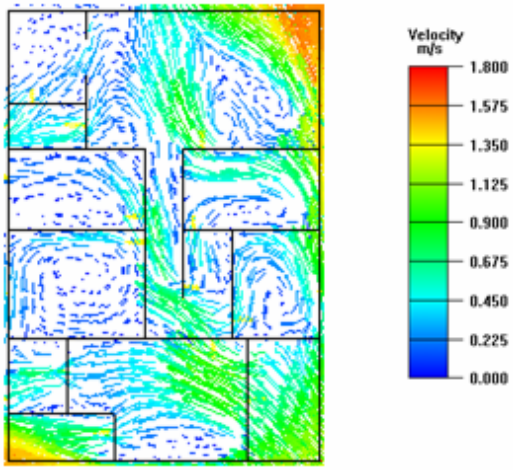

Fig.5 Velocity field across Y=1.5m in

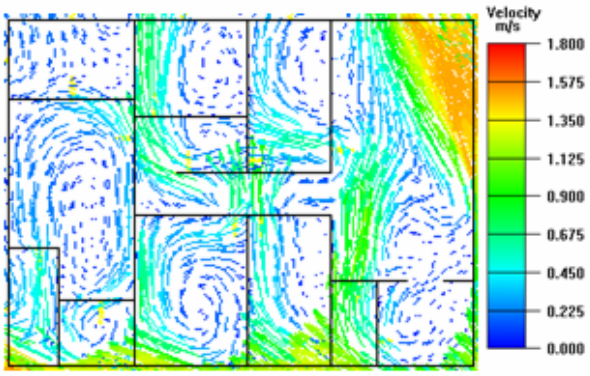

Fig.6 Velocity field across Y=1.5m in the west apartment

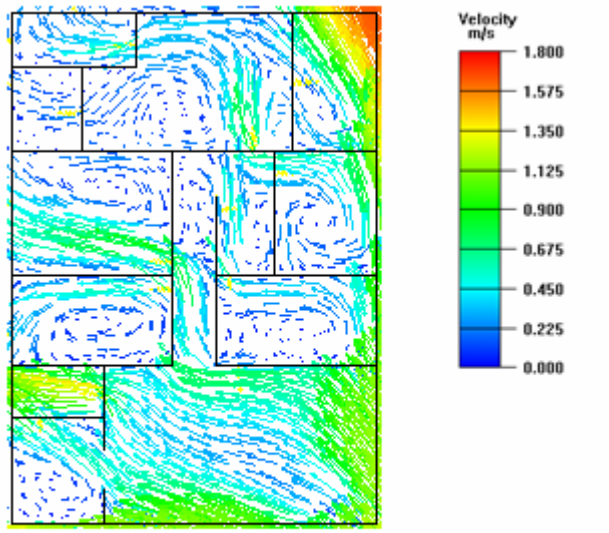

Fig.7 Velocity field across Y=1.5m in the north apartment

From Fig.4, the ventilation field of apartment in east direction shows ventilation can remove the air of kitchen effectively. The pollutants and smoke produced during cooking are eliminated by wind from the window on the left wall in the dining room. They cannot spread into other rooms. More and more researches indicate that the pollutants and smoke which are brought by cooking lead to lots of diseases. (K. Siegmann & K. Sattle, 1996) Although living room is in the north west direction, it also can enjoy the new air which comes from balcony 3 on the south. Three bedrooms are located in south and east directions. They all have windows and doors opposite to the window, so all of them have good ventilation conditions. Because the toilet is in the inner space of the apartment, the air in it is possible pass through other rooms. Luckily in Fig.4, the only affecting room is work room, but with the help of exhaust fan, the smell and air can be excluded directly from the toilet. Above all, the apartment in the east is a good style. The ventilation in this case is favorable.

Fig.5 describes the velocity field of apartment in the south direction. Living room, work room and bedroom 1 have perfect ventilation effects. Compared with Fig.4, the supply air of bedroom 2 and bedroom 3 is not as strong as that of Fig.4. Besides this, the air of toilet can permeate two bedrooms, dining room, corridor and kitchen. Because the living room is on the east direction, the supply air is forced to occupy the whole space, the pollutants and air in the kitchen cannot flow back to dining room and living room, but they may remain in the kitchen longer than the case in Fig.4.

Fig.6 depicts the velocity field of apartment in the west direction. It is evident that ventilation of bedroom 1 is bad. Almost new air isn't directly supplied to here and there is a big vortices in this room. Since in this case kitchen is in the south east corner, the coming wind bring the pollutants and air of kitchen to the inner space of apartment which include dining room and living room. The ventilation effects of other room are nearly same to those of the case in Fig.4.

Fig.7 reveals the velocity field of apartment in the north direction. Clearly living room and dining room have best ventilation environment. Inlet and outlet form a thoroughfare to let new air pass. And the pollutants and air of kitchen cannot access the inner space of the apartment. Ventilation effects of the three bedrooms are not idea because they all located in the north or the west of the apartment. Part of air of toilet enters bedroom 1 and it has no effect on the work room.

By these four figures, it is easy to conclude the apartment in the east is optimum choice. Fig.8 explains it clearer. Wind flows almost unobstructed. Even on the other contrary side of wind origination, the velocity can maintain higher level. Draught is obvious in all the rooms.

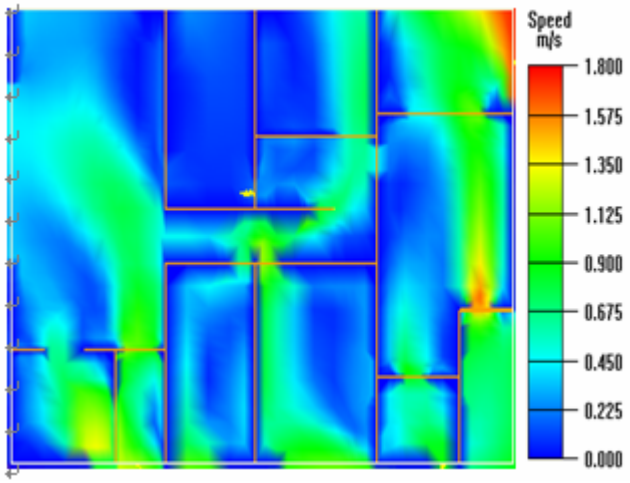

Fig.8 Velocity vector field across Y=1.5m in the east apartment

Bedrooms and living room are the main spaces for people, so they must have good ventilation conditions. When the apartment is in the designing process, designers should make different layouts

according to different direction. Both changing the size of window and revising the inner structure can improve indoor environment. Also designers can use special design to connect all rooms reasonably. Moreover people can put furniture in some place to avoid return air and vortex.

4. CONCLUSION

The winds effects on typical apartments have been simulated with a CFD approach and four issues concerning apartments in different directions are presented and discussed. In comparison with the experimental data, the relatively comfortable and energy saving apartment style in the four cases is the one located in the east direction. It is because not only the wind comes from south east direction but also its good style design. The reasonable connection of each room provides a tunnel for outdoor wind. The other three apartments should change the inner design style to let wind pass through conveniently. This paper provides a method to evaluate apartment styles and revising design.

REFERENCE

[1] Launder B E, Spalding D B. The numerical computation of turbulent flows. Computer Methods in Applied Mechanics and Engineering, 1974, 3, 269–289.

[2] Jones P J, Whittle G E. Computational fluid Dynamics for building airflow prediction. Buildings and Environment, 1992, 27, 321–338.

[3] K. Siegmann, K. Sattle. Aerosol from hot cooking oil, A possible Health Hazard. The Aerosol Science, 1996, 27,493-494.